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Restorative effects of mature and young commercial forests, pristine old-growth forest and urban recreation forest - A field experiment

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A R T I C L E I N F O

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A B S T R A C T

Urban and peri-urban forests and woodlands provide an important recreational service for citizens. However, these forests are facing increasing pressure due to the ongoing land-use encroachment and increased demands for wood-based products. Same time the world is getting more urbanized and living in cities is associated with mental health problems and exposure to air pollution and noise. Conversely, forests are known to create more healthy environments, and the need for effectively restorative forests is even more evident. In this study we investigated whether the restorative effects of forests on people vary according to the forests' different management decisions and/or ages. We selected four spruce-dominated forests that represent well the different management outcomes: 1) an urban recreation forest, 2) a mature commercial forest, 3) a young commercial forest, and 4) an old-growth forest in its natural state. The study participants (39 women and 27 men) visited each forest once. The experiment included 15 min of observation, followed by 30 min of walking. We measured the restorative effects: perceived restorative outcomes, vitality and positive and negative emotions. The restorative effects increased significantly in all forests. The old-growth forest and mature commercial forest were significantly most restorative. The urban recreation forest was less restorative than these two, but more restorative than the young commercial forest which was at least restorative. In conclusion, it is important to preserve forests with old stands close to residential areas. As the forest management decisions and stand age affect restorative qualities, they should be taken into account in forest management and land use planning.

1. Introduction

1.1. Nature promotes well-being

Prolonged stress is an substantial public health risk, which negatively affects physical and mental health (Hammen, 2005). Same time the urbanization is a growing trend and living in cities is associated with higher risk of mental health problems (Gruebner et al., 2017). An increasing number of studies indicate that short-term visits to nature contribute to mental health through restoration (Beil and Hanes, 2013; Tyrväinen et al., 2014; White et al., 2013) and eventually reduce stress (Hartig et al., 2003). Many studies show that visits to nature have several restorative effects. For example, nature experiences increase positive and decrease negative mood states (Hartig et al., 2003; Park et al., 2011; Tsunetsugu et al., 2013), increase perceived restoration (Pasanen et al., 2018; van den Berg et al., 2003), vitality (Tyrväinen et al., 2014; White et al., 2013), and support the renewal of directed attention capacity (Hartig et al., 2011).

Environmental psychology has mainly used two theories to explain the pathways towards restoration in nature. According to the attention restoration theory (ART), the term 'restoration' refers to the processes that people go through when recovering from something that has reduced their ability to cope with their everyday life tasks and demands (Hartig et al., 2011). The alternative theory on restorative environments is the stress reduction theory (SRT), which is based on the assumption that the natural environments that support survival can evoke rapid positive emotions and block negative emotions (Markevych et al., 2017; Ulrich and Simons, 1991). Besides these two theories, the feeling of revitalization after being in a restorative environment has a consistent pattern (Ryan et al., 2010). Vitality is defined as 'having physical and mental energy' (Ryan et al., 2010) and is associated with many non-activated positive states such as satisfaction, contentment and happiness (Nix et al., 1999).

Despite the increase in research into the role and importance of nature in restoration, it is unclear what types of nature stimulate restoration the most. Most studies have compared the restorative effects of green areas to those of built areas after exposure to these areas (Bowler et al., 2010; Hartig et al., 2003; Lee et al., 2009), and have

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found that a natural setting reduces stress more effectively. A large body of studies has focused on the health effects of physical exercise in green environments (Li et al., 2008; Plante et al., 2007; Shanahan et al., 2016), and found similar results. Most of the areas studied have been urban green areas, typically man-made parks or managed recreation forests. Currently, there is little evidence based on field experiments examining how different nature areas support restoration (see Ojala et al., 2019; Tyrväinen et al., 2014) and even less field studies have compared the well-being effects of different forests (see Martens et al., 2011; Sonntag-Öström et al., 2014; Takayama et al., 2017). There is a gap in the knowledge on whether different types of forest have different restorative effects. For example, we do not know how different types of forest management regimes, for example management applied in commercial forests, recreation forests or protected areas affect perceived health or benefit well-being.

In many countries, urban and peri-urban forests and woodlands provide an important recreational service for citizens. In Finland, for example, forests are the most typical environment for physical activity (Husu et al., 2011), and most residents' favourite place in nature, even in cities and towns, are often forested areas (Korpela et al., 2010). Social value mapping studies in Helsinki have shown that most valued green areas are typically relatively large forest areas (Tyrväinen et al., 2007). Despite the increased understanding that well-being effects are linked to the recreational use of forests, heavy land-use pressures in urban and peri-urban areas across Europe have reduced the availability and quality of forests for public use (Tyrväinen et al., 2017). Moreover, amenity values are often understated in forest management, even in urban and peri-urban forests, where use intensities are the highest. Commercial forests located in rural areas deliver significant well-being effects linked to, for example, growing nature-based tourism. However, intensive forest management in these areas mainly targets timber production, which decreases the suitability of the forests for recreation (Silvennoinen, 2017). Thus, we need to study how different forest management regimes may affect restoration outcomes.

1.2. Forests as restorative environments

Previous research results regarding how restorative experiences vary in different types of forest are fragmented. Experimental study results regarding how the quality of forests affects people's perceived restoration are somewhat contradictory. Martens, Gutscher, & Bauer (2011) studied whether 'wild' and tended urban forests influence well-being differently. They found that after a walk, the positive affect was greater and the negative affect smaller in a tended forest, compared to a wild forest (Martens et al., 2011). However, the 'wild' forest had been out of commercial use for only six years, and was located in an urban area, so the result might have been different if the forest had been without human interference for a longer time and had been located in a rural area. Takayama et al. (2017) compared whether viewing the dense forest and forest that was managed with thinning, have different restorative effect. They found no significant difference on restoration outcome and feelings of positive and negative affect between the forests, but the thinned forest was described more bright and open compared to a dense forest. However, the forests in the field experiment were plantation forests and not pristine. Tomao et al. (2018) found that increased stand density and shrubs – common in more natural forests – negatively influenced the perception of the psychological benefits of forest visits, whereas Chiang et al. (2017) found that when observing the forests from 3D images, the vegetation density made no difference to stress levels. In a recent meta-analysis of studies conducted in lab and field conditions, contact with managed and wild nature had similar effects on emotional wellbeing (McMahan and Estes, 2015), but a study involving looking at photos and watching videos found that the more natural the environment seemed, the more restorative it was (Carrus et al., 2013). However, a number of studies of the effects of forest management decisions on restorative effects have been conducted in different cultural and geographical conditions in which the concept of wildness, as well as its appreciation, may vary. Studies in which people self-assess their feelings in nature areas have also shown that different natural environments affect well-being in different ways (De Vries et al., 2003; Hinds and Sparks, 2011; Marselle et al., 2014).

As studies of the restorative effects related to the different management regimes are limited, we can obtain useful information from forest landscape preference studies. It is important, however, to note that a preference for a specific environment does not directly mean that the environment is highly restorative. Nevertheless, the preference studies describe forest environments that people look for and want to visit. In general, people appreciate mature forests with good visibility and some undergrowth, whereas younger forests are less preferred (Silvennoinen et al., 2002; Stoltz et al., 2016; Tyrväinen et al., 2017). Natural-looking forests or forests that are perceived as being in their natural state with no direct evidence of cuttings such as stumps, logging waste or soil tillage are preferred (Silvennoinen, 2017; Tyrväinen et al., 2017). Often, a mature forest with large-dimensioned trees, in which it is easy to walk, is valued for recreational purposes (Frick et al., 2018; Silvennoinen et al., 2002). Similarly, the view after clear-felling is the least preferred environment (e.g. Gundersen and Frivold, 2008; Kearney and Bradley, 2011; Ribe, 2009). In addition, people do not usually like dead or fallen trees (e.g. Gundersen et al., 2017; Gundersen and Frivold, 2008; Tyrväinen et al., 2003) but the greater awareness of importance of forest ecology may improve perceptions of dead wood (Tyrväinen et al., 2003; Brunson and Reiter, 1996). Based on these preference studies, we may conclude that not all types and sizes of forest are equally effective in terms of well-being. To our knowledge, no studies have compared how different types of forest management choices affect the restorative effects of forests at different phases of the stand development.

1.3. Objectives of the study

The main objective of this study was to investigate the restorative effects of short visits to four different types of forest that differ in terms of their management and/or age. These experimental forest stands were: a) an urban recreation forest (Urban), b) an old-growth forest (Pristine), c) a mature commercial forest (Mature) and d) a young commercial forest (Young).

Previous research evidence has confirmed that forests are typically experienced and perceived as restorative environments. Therefore, we hypothesized that: 1) all four forests would have restorative effects on people (increase in perceived restorative outcomes, subjective vitality and positive emotions, and decrease in negative emotions). Based on previous forest preference studies, we also hypothesized that: 2) the three older forests would have significantly stronger restorative effects than the younger forest and: 3) there would be differences between the restorative effects of the natural state forest (old-growth forest) and the managed forest (mature commercial forest) in a rural location. We did not specify the third hypothesis any further, because according to preference studies, on average people prefer lightly managed mature forests that also look natural.

2. Methods

2.1. Study sites and their selection

This study replicated to some extent the study design previously used in the field experiment in Helsinki, Finland by Tyrväinen et al. (2014). We used the same forest, Keskuspuisto – Helsinki Central Park, in this study as our control environment, because its positive effects on human stress reduction were already known.

The urban Central Park recreation forest (Urban), is the largest forested area in Helsinki (see Fig. 1 and Table 1). We conducted our field experiment in the northern part of this park, approximately 11 km

Table 1
Forest characteristics.

Forest site	Urban	Pristine	Mature	Young
Location	Helsinki/urban	Sipoo/rural	Sipoo/rural	Sipoo/rural
Age	95	> 120	100	40
Stand basal area (m^2/ha)	30	36	32	35.1
Tree height (m)	26	33	27	16
Diameter breast height, d.b.h (cm)	30	35	28	16
Stand wolume (m^3/ha)	370	524	403.1	298.5
Dominant tree species	Spruce (*Picea abies*)	Spruce (*Picea abies*)	Spruce (*Picea abies*)	Spruce (*Picea abies*)
Other tree species	Few: pine, birch, aspen, rowan	Few: pine, birch, aspen, rowan	Few: pine, birch, aspen, rowan	Few: pine, birch, rowan

from the city centre. The area is a 95-year old spruce dominated forest with high biodiversity values. It has wide walking and cycling trails and several smaller footpaths. The forest in the experiment area had been managed rather lightly for recreational use and consisted of a notable amount of dead wood. However, because it was heavily used for recreational purposes, it had traces of erosion.

The old-growth forest was a large pristine forest area belonging to the Natura 2000 network of protected areas (see Fig. 2 and Table 1). The area is a spruce dominated, over 120-year old forest that has remained unmanaged for several decades. The forest is rich in biodiversity, with species related to old forests. It has an extensive amount of dead standing and lying decaying trees, partly due to the recent damage caused by the European spruce bark beetle (*Ips typographus*). It also has multi-layered canopies and gaps, which are typical for old-growth forests. Recreation use is low.

The mature commercial forest was located near the Sipoonkorpi national park and had recently harvested clear-cut area nearby (see Fig. 3 and Table 1). This forest is a spruce dominated forest and is approximately 100 years old. Its appearance is similar to that of the urban recreation forest, but its general look is more managed, and it has less recreational infrastructure/trails. The stand has an even-aged structure but some dead wood has been left lying to increase biodiversity. Recreation use is low.

The young commercial forest was located near agricultural fields. It is approximately 40 years old and has a spruce dominated monoculture (see Fig. 4 and Table 1). The forest has been actively managed for timber production and thinning residues have been left on the site. Recreation use is low.

As the urban recreation forest (the control environment) was spruce-dominated, the other forests we chose were also spruce-dominated – this helped avoid any differences in effects between the sites resulting from varying dominant tree species. Moreover, in Southern Finland, spruce is typical and in the Uusimaa region, where the experiment was conducted, it is the most dominant tree species, covering 40.1% of forest land.

In addition to the spruce-dominance across the experimental sites,

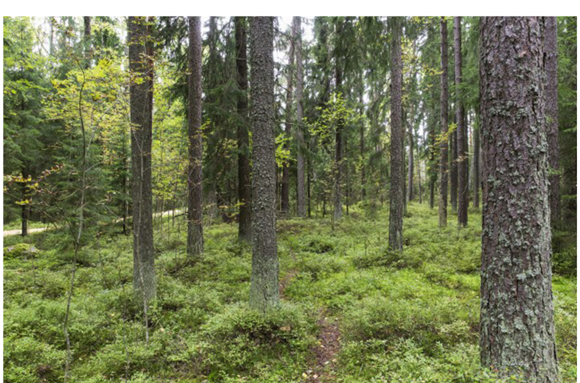

Fig. 1. The urban recreation forest (Urban).

Fig. 2. The old-growth forest (Pristine).

Fig. 3. The mature commercial forest (Mature).

Fig. 4. The young commercial forest (Young).

the purpose was to choose forests typically found in the region and used for recreation purposes. According to forest landscape preference

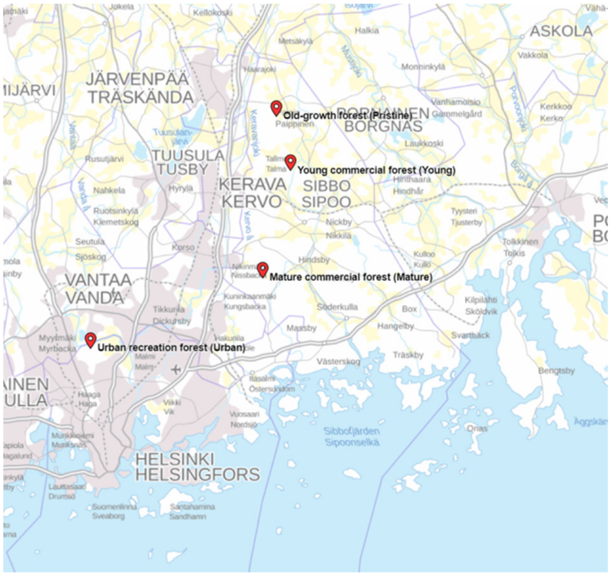

Fig. 5. Experimental forests (contains data from the National Land Survey of Finland Background map series, 10/2019).

studies, people prefer mature forests for recreation, and thus we chose a mature commercial forest (Mature) and an old-growth forest (Pristine) as our experimental forests. We also chose a young commercial forest (Young), as these are typical in Southern Finland (Uusimaa region), and 40.2% of forest land is young forests (age < 40 years) (Natural Resources Institute Finland, Luke, 2017). Forty per cent of the other age classes are middle-aged forests (age 40–80 years), 15.4% are mature forests (81–120 years) and only 3.5% are old-growth forests (age over 120 years, and have developed naturally without forest management).

When selecting the potential forests for the experiment, we outlined all the forests that were located no further than a 45-minute drive from our starting point in the Pasila district, near the local railway station in Helsinki. The forests had to be located outside the flight noise zone, with no or a low amount of traffic noise, and their size had to be relatively large, allowing a 30-minute walk in the forest. The urban recreation forest was located in Helsinki, the capital of Finland with almost 650 000 inhabitants. The other three forests were located in a rural area in the municipality of Sipoo located next to Helsinki (see Fig. 5). We chose forests that were easily accessible and best available for the experiment in the Helsinki region. None of four forests had water courses or major height differences, because we wanted to control for the effects of water environments often associated with high feelings of restoration (White et al., 2010, 2013) and the possible restorative effects of physical exercise in a varying terrain (e.g. Marselle et al., 2014). All the forests were larger forested areas of more than 100 ha.

2.2. Recruitment

The volunteers we recruited were both women and men who had lived in the Helsinki metropolitan area for at least two years. We avoided recruiting residents who had recently moved from the countryside to the Helsinki metropolitan area. They had to be full-time employees, as we wanted to study the restorative effects of nature after a working day.

We sent email invitation letters to several corporate human resource managers and distributed the invitation through various social media channels. The invitation included a link to a Webropol survey and provided a phone number and email address as an alternative for signing up for the experiment. Altogether 222 volunteers pre-signed. The first invitation round interested mostly women and so we launched another invitation round targeted at men. From these two calls, we excluded 29 volunteers because they did not live in the Helsinki metropolitan area, nine because they were not currently working and two because their work was thematically related to nature and well-being, which could potentially lead to biased results. We contacted the remaining 182 pre-signed volunteers via phone or e-mail. In order to ensure we had participants with varying backgrounds and interests in nature, we used several selection criteria, including age, gender, profession, background in nature conservation issues, studies related to nature, possible connections to the forest industry, and forest ownership. Many cancelled their participation as they were unable to find adequate time for all four visits. The final study sample consisted of 70 participants, 66 of whom visited all four study sites. Three who visited only one site and one who visited three sites were excluded from the final data analyses.

Before the first day, all the assigned participants received an information package and a background information questionnaire by post. In the information package, we presented the study's procedure, voluntary nature and confidentiality, as well as funding information and the contact information of the research personnel. We told them that our aim was to study what kind of nature is restorative, but we did not tell them that all the sites they would visit would be forests. We also advised them on clothing, how to find the meeting point and the exact dates and times of all four visits.

The participants gave written consent for their voluntary participation after receiving instructions on how the experiment would be carried out and information on their rights based on principles of the Declaration of Helsinki, adopted by the World Medical Association. All the necessary information regarding the study was given and the study did not expose the participants to any harm. Therefore, according to the Finnish Advisory Board on Research Integrity, an ethical review of the study was not required. The participants did not receive any incentives for participating to the study.

2.3. Measures

We asked several background questions before the first visit day, such as weekly working hours, childhood dwelling area, household income, education, current self-evaluated health status and physical condition, membership of nature conservation organizations, forest ownership and work related to nature. We also asked how stressful the participants perceived their day at work on a scale of 1–5 (1 = not at all; 5 = very stressful), and some measures, which are not reported in this article due to space limits.

During the experiment, we used several psychological before-after scales to measure the participants' self-reported restorative effects. We also asked how focused the participants were on the current environment sounds in comparison to other than nature sounds (sound focus) on a scale of 1–7 (1 = not at all; 7 = completely). With similar scale, in order to find out whether the group situation affected to participants, we asked how alert they were on other people around. We measured the environmental noise levels during the experiment using the Larson Davis noise dosimeter, model 706RC.

2.4. Before-after measures

We used three different scales to measure the restorative effects, such as restorative outcomes, vitality and mood states in each of the four forests. Each scale consisted of items rated on a seven-point Likert scale (1 = not at all; 7 = extremely).

The Restoration Outcome Scale (ROS) (Hartig et al., 1998; Korpela et al., 2008; Staats et al., 2003) has six items of which three measures relaxation and calmness ('I feel restored and relaxed',' I feel calm', 'I have enthusiasm and energy for my everyday routines'), one item measures attention restoration ('I feel focused and alert') and two items measures clearing one's thoughts ('I can forget everyday worries', 'My thoughts are clear').

The Subjective Vitality Scale (SVS) has four items: 'I feel alive and vital', 'I don't feel very energetic', 'I have energy and spirit' and 'I look forward to each new day' (Ryan and Frederick, 1997).

The Positive and Negative Affect Schedule (PANAS) is commonly used in nature and well-being studies (Marselle et al., 2013; Takayama et al., 2014; Tyrväinen et al., 2014). It measures positive and negative affect, each with 10 items (e.g. interested, excited, strong and distressed, scared and ashamed). We calculated PANAS POS from the positive affect items and PANAS NEG from the negative affect items.

2.5. Experimental procedure

All the forests were visited in a random order and on random weekdays. In order to eliminate the order effect, each forest was coded to have similar amount of first, second, third and fourth visiting times. We choose a within subjects design where all participants visit each forest once, in order to increase the validity of the study. Approximately one participant visited one forest per week. However, several participants needed to reorganize their scheduled study days due to their own timetable changes. For this reason, some participants visited more than one forest during the same week. The participants were assigned to each forest visit independently so that nobody visited the forests in the same group, to avoid possible social effects with familiar people. The group sizes were kept small; a maximum of six people and a minimum of one person to minimize the group effect to the participants and they were instructed to focus on their own experiences and feelings.

The participants received an SMS reminder in the morning of each visit day with guidance on how to dress. We cancelled the experiment day if the weather was too bad. We collected the background information questionnaires on the first experiment day if the participants had not returned it by post. Each time, we picked up the participants from the same meeting point in Pasila, Helsinki and brought them to the experiment sites by minivan. They knew only the city of the environment prior to each visit. We asked them to avoid discussions during the drive to the site. The trip to each site took 30–40 min as we controlled the length of each journey in order to keep the driving time as similar as possible for each site.

Before entering the forest, the participants completed the first questionnaire (ROS, SVS, PANAS) in or near the minivan, after which we offered them small snacks to eat before entering the forest. We then asked the participants to be silent throughout the experiment and not to pick berries, mushrooms, etc. The first phase of the experiment involved sitting 15 minutes in chairs on-site (see Fig. 6). After sitting, the participants filled the second questionnaire (ROS, SVS) (see Fig. 7). The viewing session was followed by a 30-minute walk (see Figs. 8 and 9) led by a researcher who ensured that all the groups took the same route and adjusted the walking speed. The participants were asked to walk in line with at least two meters distance between each other. During the walk, we regularly stopped for a few minutes in order to view the environment. The route in all sites was approximately half a kilometre long and the walking speed only approximately 1.1 km per hour. Another researcher walked behind the group, carrying equipment for noise measurement. The temperature was measured before and after each experiment. The values of relative humidity measures at each visiting days were obtained afterwards from the Meteorological Institute of Finland. After walking, the participants went back to the van and completed the third questionnaire (ROS, SVS, PANAS). The whole experiment took approximately three hours. The experimental procedure contained sitting and walking on site as in several previous studies in the field and that makes the results more comparable (e.g. Park et al., 2010; Tyrväinen et al., 2014). However, in this study, we took participants inside the forest (not on paths as in most previous experiments) to experience the forest qualities better. In order to eliminate the effect of physical exercise, we arranged the sitting session first and the following walk conducted in a slow phase.

The experiments were conducted from August to the end of October in 2016, and from the end of April to the end of June in 2017. A few visits were also made in September and October 2017. We ran the experiment during the growing season when nature was green, but not during the main summer vacation season from the end of June to the beginning of August.

3. Results

3.1. Background information

3.1.1. Participants

The participants (n = 66) were 26–65 years old (M = 43.38, SD = 10.68), of which 59% were women and 74% had higher education. They worked an average of 43 h per week (SD = 7.80). The self-evaluated mean value of health condition was 1.77 (SD = .80) and physical condition 2.32 (SD = 0.88) on a five-point Likert scale (1 = very good; 5 = very poor). On average, 25% of participants felt that their current day at work was extremely or very stressful, 30% rather stressful and 44% somewhat or not at all stressful. One per cent stated they did not go to work that day. The stress level of each participant did not differ between the visiting days of all forests. (See additional information about the participants in Table 2.) The age structure in our experiment was similar in comparison to the population of the same age-groups in the municipality of Helsinki. However, women and highly educated were over-represented (51% and 45% correspondingly) (Official Statistics of Finland (OSF), 2018).

Fig. 6. Viewing session in the urban recreation forest (Urban).

Fig. 7. The researcher collecting questionnaires after the viewing session in the mature commercial forest (Mature).

Fig. 8. Walking session in the old-growth forest (Pristine).

Fig. 9. Walking session in the young commercial forest (Young).

3.1.2. Environments

When tested with paired samples t-test, there were no significant differences on temperatures between the forests, but the average noise levels (dBA) were significantly higher in the urban recreation forest compared to the other three forests ($p < .01$) (see Table 3). However, while in the forests, there was no correlation between the restorative effects and average temperature on pearson correlation or average noise (dBA) on spearman correlation.

The values of relative humidity measures at 4.00 p.m. (in the middle of the experiment) for each experimental day were obtained from the Meteorological Institute of Finland. The relative humidity values varied between 29–100% at urban recreation forest, 31–96% at old-growth forest, 31–91% at mature commercial forest and 27–98% at young commercial forest at particular visiting day. The measurements are only

Table 2
Background characteristics of the participants (percentages).

Gender	
Women	59
Men	41
Age, years	
26-35	32
36-45	26
46-55	27
56-65	15
Childhood dwelling area	
Urban centre	15
City suburb	34
Municipality centre	12
Municipality suburb	21
Rural area	18
Household income level, €/year	
Below 30 000	17
30 000–50 000	26
50 000–70 000	18
70 000–90 000	13
90 000–110 000	9
Over 110 000	17
Education	
Academic degree (bachelor, master, PhD)	74
Short-cycle tertiary education	12
High school	9
Vocational/basic level	5
Job related to nature	23
Education related to nature	21
Education related to forestry	11
Forest ownership	9

indicative and cannot be used for a more detailed analysis as the measurement point was at Helsinki-Vantaa airport which is located 5–15 kilometres from each forest.

3.2. Results of the experiment

3.2.1. Scale statistics

We calculated the mean sum scores and standard deviations for all psychological measures as well as for the focus on other than nature sounds (sound focus). These are presented in Table 3. The reverse scale items were taken into account. The reliability of all psychological measurements was good, with Cronbach´s α ranging from 0.75 to .96. When tested with paired samples t-test, other than nature sounds captured one's attention significantly more in the old-growth ($p < .01$) and young commercial forests ($p < .01$) than in the mature commercial forest and more in the old-growth forest ($p \leq .01$) than in the urban recreation forest. We can assume that the group situation did not significantly affect to the participants during the experiment, as majority, 84%, answered that they were "not at all, very little or fairly little" focused to the other people around them.

The correlations between all the psychological measures at all the measured time points and sound focus are presented in the Table A. (see supplementary data).

3.3. Results of repeated measures ANOVA and ANCOVA

We used repeated measures of analysis of variance (ANOVA) to calculate the effects of the experiment in the forests. In the analysis we used four within-subject factors; urban recreation forest (Urban), old-growth forest (Pristine), mature commercial forest (Mature) and young commercial forest (Young). We had three time points during the experiment (before entering the forest (T1), after sitting (T2) and at the end of the experiment (T3)) to measure the results of the Restoration Outcome Scale (ROS) and the Subjective Vitality Scale (SVS). The Positive and Negative Affects Scale (PANAS) was measured before and after the experiment (T1 and T3). For ROS and SVS we ran six models to obtain all the contrasts with the reference categories: Urban and T1; Urban and T2; Pristine and T1; Pristine and T2; Mature and T1 and Mature T2. For PANAS POS and PANAS NEG we ran three models: Urban and T1, Pristine and T1, Mature and T1. We adjusted the estimates of sphericity using the Greenhouse-Geisser correction when sphericity was violated according to Maulchly's test.

The repeated ANOVA also revealed that there were no differences on the restorative effects between the forests before entering the forest (T1). As the original coded visiting order changed because several participants needed to reorganize their scheduled study days, we confirmed with repeated measures of analysis of covariance (ANCOVA) that the visiting orders did not have an effect to any of the psychological measurements.

3.4. Results of restoration outcome scale

The Forest site had no significant main effect ($F(3, 195) = 0.08$) but Time had a significant main effect ($F(1.42, 92.16) = 108.34$, $p < .01$) on the perceived restorative outcomes. Contrasts revealed significant differences between all three time points (see Table 4). There was also a significant interaction effect between Forest site and Time during the experiment ($F(4.92, 320.05) = 4.37$, $p < .01$).

The interaction effect revealed that the mature commercial forest and old-growth forest were significantly more restorative compared to young commercial forest and urban recreation forest on T3 vs. T2 and

Table 3
Scale statistics of psychological measures and environmental variables in four forests during experiment.

Forest site	Urban			Pristine			Mature			Young		
Measures	Mean	SD	Cron α	Mean	SD	Cron α	Mean	SD	Cron α	Mean	SD	Cron α
At the beginning												
ROS	4.37	.95	.90	4.31	1.00	.91	4.30	.85	.86	4.40	.91	.87
SVS	4.55	.96	.84	4.38	1.14	.87	4.43	.98	.79	4.55	1.03	.87
PANAS POS	4.15	.88	.91	4.05	.94	.92	4.04	.82	.89	4.11	.82	.88
PANAS NEG	1.85	.71	.86	1.86	.70	.83	1.85	.70	.86	1.83	.69	.84
After viewing												
ROS	4.98	.97	.91	4.95	.92	.90	4.97	.90	.90	5.10	.81	.88
SVS	5.12	.93	.82	5.01	.89	.84	5.03	1.02	.80	5.12	.95	.81
After walking												
ROS	5.23	.88	.91	5.47	.73	.87	5.43	.92	.93	5.15	.88	.92
SVS	5.43	.83	.82	5.52	.88	.84	5.50	.95	.82	5.22	.92	.85
PANAS POS	4.72	.96	.92	5.00	.91	.91	4.95	.98	.92	4.46	.99	.91
PANAS NEG	1.45	.56	.89	1.37	.38	.75	1.37	.43	.81	1.52	.59	.87
Sound focus	3.48	1.5		4.14	1.63		3.11	1.40		3.95	1.48	
Temperature, °C	14.8	4.4		15.8	4.2		15.9.	5.8		15.3	4.8	
Noise, dBA	55.1	2.9		50.7	4.9		48.2	3.3		50.0	3.3	

Table 4
Results of simple contrasts in repeated-measures ANOVA, F statistics (with degrees of freedom 1, 65) and the effect sizes.

Forest site	Time	Measure							
		ROS		SVS		PANAS POS		PANAS NEG	
		F	r^1	F	r^1	F	r^1	F	r^1
Urban vs Pristine		.16	.05	.36	.07	.84	.11	.22	.06
Urban vs Mature		.13	.05	.16	.05	.50	.09	.41	.08
Urban vs Young		.04	.02	.46	.08	2.57	.20	.22	.06
Pristine vs Mature		.01	.01	.03	.02	.12	.04	.01	.01
Pristine vs Young		.08	.04	.01	.01	8.25**	.34	1.00	.12
Mature vs Young		.02	.02	.06	.03	4.77*	.26	1.06	.13
	T2 vs T1	124.73**	.81	88.56**	.76	–	–	–	–
	T3 vs T1	127.37**	.81	129.67**	.82	90.48**	.76	80.86**	.74
	T3 vs T2	36.33**	.60	95.69**	.77	–	–	–	–
Interaction									
Urban vs Pristine	T2 vs T1	.05	.03	.39	.08	–	–	–	–
	T3 vs T1	6.29*	.30	3.86	.24	9.17**	.35	1.07	.13
	T3 vs T2	6.07*	.29	5.10*	.27	–	–	–	–
Urban vs Mature	T2 vs T1	.22	.06	.14	.05	–	–	–	–
	T3 vs T1	5.57*	.28	3.30	.22	8.74**	.34	1.54	.15
	T3 vs T2	6.21*	.30	4.96*	.27	–	–	–	–
Urban vs Young	T2 vs T1	.82	.11	.00	.01	–	–	–	–
	T3 vs T1	.87	.12	3.40	.22	3.03	.21	1.22	.14
	T3 vs T2	4.49*	.25	5.78*	.29	–	–	–	–
Pristine vs Mature	T2 vs T1	.05	.03	.05	.03	–	–	–	–
	T3 vs T1	.05	.03	.31	.07	.15	.05	.06	.03
	T3 vs T2	.29	.07	.21	.06	–	–	–	–
Pristine vs Young	T2 vs T1	.26	.06	.29	.07	–	–	–	–
	T3 vs T1	9.12**	.35	12.32**	.40	28.34**	.55	4.35*	.25
	T3 vs T2	18.87**	.47	16.82**	.45	–	–	–	–
Mature vs Young	T2 vs T1	.07	.03	.06	.03	–	–	–	–
	T3 vs T1	6.89*	.31	10.04**	.37	20.84**	.49	3.65	.23
	T3 vs T2	27.02**	.54	19.29**	.48	–	–	–	–

Note. **F is significant at $p < .01$ level. *F is significant at $p < .05$. [1] = r is the effect size, the relationship between the independent and dependent variable, ranging from .00–1.00. The interpretation of effect sizes is as follows: small > .10, medium > 0.30, large > 0.50 and very large > 0.70 (Cohen, 1988).

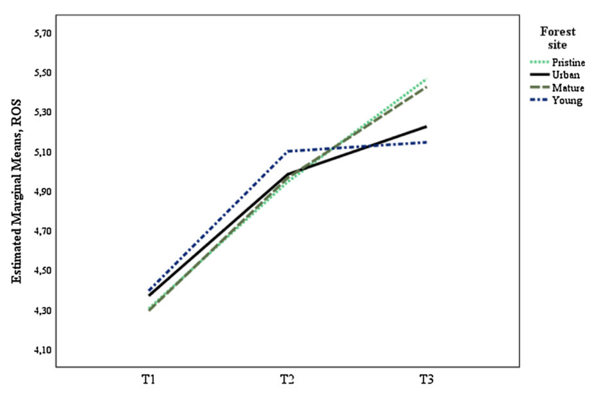

Fig. 10. Interaction graph for Restoration Outcome Scale. The type of forest is represented by four lines on three time points. *Note.* T1 = before entering the forest, T2 = after sitting, and T3 = at the end of the experiment.

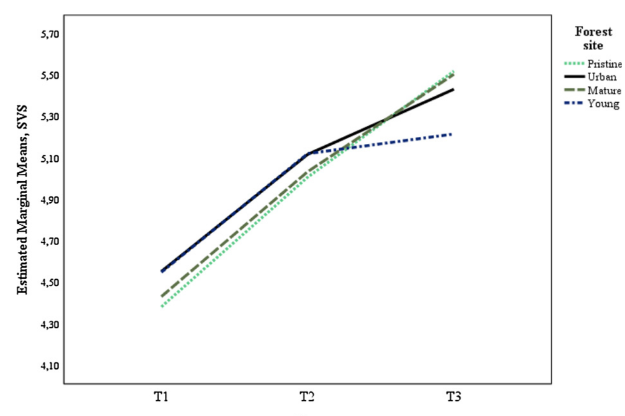

Fig. 11. Interaction graph for Subjective Vitality Scale. The type of forest is represented by four lines on three time-points. *Note.* T1 = before entering the forest, T2 = after sitting, and T3 = at the end of the experiment.

T3 vs.T1 (see Fig. 10). The urban recreation forest was perceived as significantly more restorative between T3 vs. T2 compared to the young commercial forest.

3.5. Results of subjective vitality scale

The Forest site had no significant main effect ($F(3, 195) = .18$) but Time had a significant main effect ($F(1.22, 79.34) = 112.58$, $p < .01$) on the ratings of subjective vitality. Contrasts revealed significant differences between all three time points (see Table 4). There was also a significant interaction effect between Forest site and Time during the experiment ($F(4.75, 309.05) = 4.78$, $p < .01$).

The interaction effect revealed that the mature commercial forest and old-growth forest were significantly more vitalizing compared to young commercial forest on T3 vs. T2, and T3 vs. T1 (see Fig. 11). The urban recreation forest was perceived as significantly more vitalizing between T3 vs. T2 compared to the young commercial forest, but it was significantly less vitalizing compared to old-growth forest and mature commercial forest on T3 vs. T2. However, between T3 vs. T1, the urban recreation forest was perceived as equally vitalizing with the mature commercial forest and the old-growth forest.

3.6. Results of positive and negative affect scale

Both the Forest site ($F(3, 195) = 2.77$, $p < .05$) and Time $F(1, 65)$

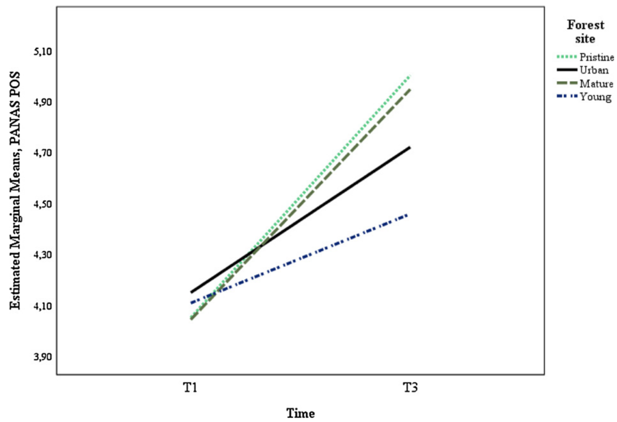

Fig. 12. Interaction graph for PANAS POS. The type of forest is represented by four lines on two time points. *Note.* T1 = before entering the forest and T3 at the end of the experiment.

= 90.48, p < .01) had significant main effects on positive emotions during the experiment. There was also a significant interaction effect (F (3, 195) = 11.27, p < .01) between Forest site and Time on positive emotions during the experiment.

The interactions revealed that the positive emotions were significantly higher in the old-growth forest and mature commercial forest compared to the young commercial forest and the urban recreation forest on T3 vs. T1 (see Fig. 12 and Table 4).

Forest site had no significant main effect on negative emotions (F(3, 195) = 0.48), but Time did (F(1, 65) = 80.86, p < .01). There was no significant interaction effect (F(2.65, 170.05) = 2.04, p = 0.12) between Forest site and Time on negative emotions during the experiment (see Fig. 13). However, there was a small effect difference between the old-growth forest and young commercial forest between T3 vs. T1 (see Table 4).

4. Discussion and conclusions

4.1. Restorative effects of four different forests

In this study we investigated the restorative effects (feelings of restoration (ROS), vitality (SVS), and mood (PANAS)) of short visits to four forests that differed in terms of their management and/or age. The results confirmed our first hypothesis: all four forests increased feelings of restoration, vitality and positive emotions, and decreased negative emotions. This is consistent with several previous studies on restorative forest environments (e.g. Park et al., 2010; Tsunetsugu et al., 2013; Tyrväinen et al., 2014).

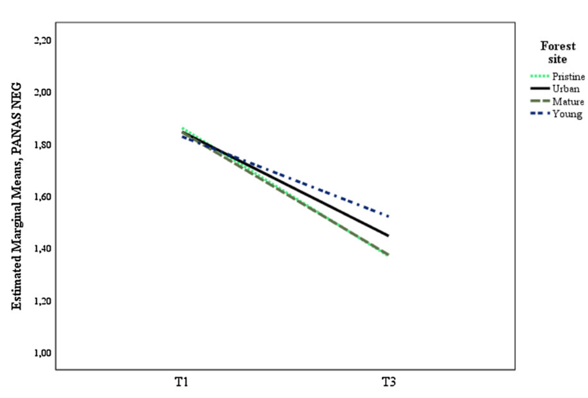

Fig. 13. Interaction graph for PANAS NEG. The type of forest is represented by the four lines on two time points. *Note.* T1 = before entering the forest and T3 = at the end of the experiment.

The results also confirmed our second hypothesis: the three older forests; the old-growth forest, the mature commercial forest and the urban recreation forest had stronger restorative effects compared to the young commercial forest. The feelings of restoration, vitality and positive mood had increased more in these three older forests by the end of the experiment compared to the young forest. Negative emotions decreased in time in all the environments. These results are in line with findings of forest preference studies and demonstrate that young forests are preferred less than older forests (e.g. Gundersen and Frivold, 2008; Silvennoinen et al., 2002). The three older forests all had similar, often highly valued forest characteristics such as old trees, and were natural or natural looking, with no direct signs of forest management (e.g. Gundersen and Frivold, 2008; Silvennoinen, 2017; Tyrväinen et al., 2017). They also had landscape features that are typically appreciated, such as relatively open stand structure with good visibility and only some undergrowth. The young commercial forest was a typically managed even-aged commercial forest with no or little variation in tree age, stand structure or variety in openness, which are known to have a stronger restorative effect (Tomao et al., 2018). During the walking part of the experiment, the participants had to make their way around some logging residues, and this might have affected the restorative effects to some extent.

We also hypothesized that the restorative effects of the natural state forest and managed forest would differ. Therefore, we compared the old-growth forest and the mature commercial forest, which were both located in the rural area. The results show no differences between the restorative effects of these two forests. This result is interesting, because according to preference studies, a mature managed forest is often the most preferred for recreation. These studies have not, however, typically included old-growth forests, and have mainly focused on understanding the effect of forest management on recreational values, not on psychological well-being (e.g. Gundersen and Frivold, 2008; Silvennoinen et al., 2002). In the study of Martens et al. (2011), the perceived attractiveness did not differ between tended and wild forest even though the impact for well-being did. Moreover, the effect of well-being seemed to remarkably depend also on the activity performed in the forest. The study is, however, one of the few that have explored linkages between preferences for forest environments and the restorative effects of different forest and therefore, further studies are needed.

One significant difference between these two forests was the amount of dead and decaying wood, which is important for biodiversity. Although the old-growth forest had much dead wood and woody debris and walking was more difficult in some places, it was not found to decrease its suitability for restoration. Some previous studies have positively connected dead wood to presence of wildlife and to perceived naturalness (Dandy and Van Der Wal, 2011) but others have linked dead wood to sad or frightening thoughts (Sreetheran and van den Bosch, 2014). Furthermore, Frick et al. (2018) noted that the acceptance of dead wood has changed over time, together with preferences for maintenance. Overall, the perception of dead or decaying wood probably depends on individual attitudes and values, knowledge bases, cultural backgrounds and nature relatedness (Martens et al., 2011; Tyrväinen et al., 2003).

In this study we also found differences between the restorative effects of old-growth and mature commercial forest compared to urban recreation forest. By the end of the experiment the feelings of restoration, vitality and positive mood had increased more in the old-growth forest and the mature commercial forest compared to the urban recreation forest. This result may be linked to the location of the study areas, as it has been suggested that forests outside cities in rural areas provide more restorative effects than urban forests (e.g. Roe and Aspinall, 2011; White et al., 2013). Moreover, crowding (Arnberger, 2006) and noise (Benfield et al., 2010) are known to have negative effects on recreational values in nature. In our study, the urban recreation forest had the highest noise level (dBA) of all the sites, the most footpaths and the highest number of visitors, due its easy accessibility for urban residents, whereas the mature commercial forest and the old-growth forest had low recreational use, low signs of trampling and a lower noise level.

One of the strengths of this study was its relatively large sample size (n = 66) compared to other experiments conducted in this field, (Lee et al., 2019, 2011) and the fact that the participants were both women and men compared to the studies where the participants were mainly women or men (e.g. Lee et al., 2009, 2011; Park et al., 2008; Tsunetsugu et al., 2013; Tyrväinen et al., 2014). Moreover, the experiment was conducted in a real-life situation with full-time employees who arrived at the experiment after their working day. Sample representativeness in our study was satisfactory as regards to the age structure in our experiment in comparison to the population in the municipality of Helsinki. However, there were more women and participants with higher education in our sample (Official Statistics of Finland (OSF), 2018) and therefore we should be careful with generalizing our results. We might also have had participants more interested in nature as on average.

There were also some limitations to selecting the actual sites, although the experiment itself was successful. It was difficult to find forests in or near the Helsinki Metropolitan area that would fulfil our selection criteria and be relatively easy to access. The mature commercial forest we chose was somewhat older, 20 years, than recommended in forest management guidelines for regeneration in southern Finland (Äijälä et al., 2014). Therefore, it also probably had more coarse woody debris and decaying wood, which are key indicators of biodiversity, than on average. In this sense, the amenity values of the stand might have been somewhat above average. Moreover, there was also more airborne noise in the study sites which was not possible to predict in advance. Some flight routes ran more often over the old-growth forest and young commercial forest because of a runway renovation at Helsinki-Vantaa airport. In these two forests, the respondents stated that they had paid significantly more attention to other than nature sounds compared to when they had been in the mature commercial forest and more in the old-growth forest compared to when they had been in urban recreation forest. However, as we did not specifically measure airborne noise, we do not know whether this affected restoration. The general average noise level (dBA) was only significantly higher in the urban recreation forest.

4.2. Future perspectives and implementation

Our results offer new information for land use planning and the management of recreation forests. This study shows that it is beneficial for well-being to conduct short visits to large forest areas but that it is even more beneficial to visit old, natural state or natural looking forests for longer than 15 min in order to maximize restorative effects. The result that the urban recreation forest was less restorative than the same age-level mature commercial forest in rural area, indicates that it is important that recreation forests remain as large as possible, so that recreation pressure and traffic noise does not become too high and the trail network is wide enough but not too dense.

All the forests in our study were effective in stress reduction and restoration, but forest management also had an effect. Previous studies (Takayama et al., 2017; Martens et al., 2011) suggest that some forest management may improve restorative qualities of the forest, but our results show that both managed and natural state old forests have higher restorative values than young forests. In Finland, the rotation cycles have become shorter due to intensified wood production and therefore, forest is often regenerated before it provides the most effective restorative effect. In particular after clear-cut, it takes decades before forest provides health benefits effectively. These aspects obviously decrease the potential of commercial forests to provide high quality restorative environments and therefore, the health benefits should be acknowledged when managing the forests close to residential areas. Moreover, the old-growth forest seem to provide high restorative effects, and hence preserving these forests for public use is important while taking care of the security aspects along paths and roads in maintenance.

It would be important to study the restorative effects of different management alternatives such as continuous cover forestry, different stand structure (measures of tree density, distribution of canopy layers, etc.) and the difference of main tree species in different vegetation zones, where the forest vegetation, structures and their management differ significantly. Moreover the season also may considerably effect to restorative potential of forests (e.g. Tyrväinen et al., 2017; Bielinis et al., 2019). The possible effect of individual characteristics such as gender, age and relatedness to nature should also be further studied.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ufug0.2019.126567.

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